Study Group 18

ELECTRONIC FUNDAMENTALS

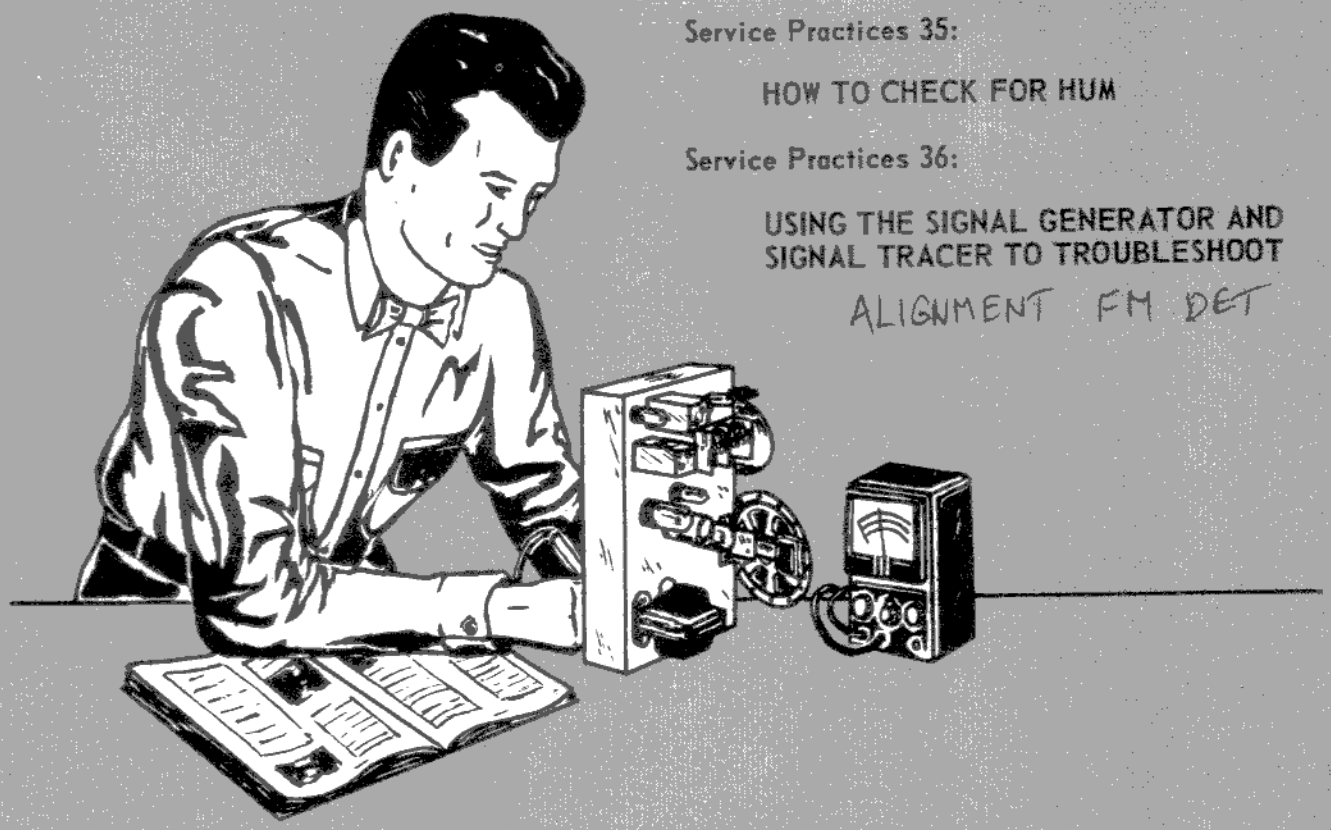
Service Practices 35:

HOW TO CHECK FOR HUM

Service Practices 36:

USING THE SIGNAL GENERATOR AND SIGNAL TRACER TO TROUBLESHOOT

ALIGNMENT FM DET



RCA INSTITUTES, INC.

A SERVICE OF RADIO CORPORATION OF AMERICA

New York, *N. Y.*

ELECTRONIC FUNDAMENTALS

SERVICE PRACTICES 35

HOW TO CHECK FOR HUM

35-1. Hum Heard Even with Volume Control at Minimum Setting

35-2. Hum Audible at Normal But Not at Minimum Volume-Control Setting, with Station Tuned In or Out.

35-3. Modulation Hum

RCA INSTITUTES, INC.

A SERVICE OF RADIO CORPORATION OF AMERICA

HOME STUDY SCHOOL

350 West 4th Street, New York 14, N. Y.

Service Practices 35

INTRODUCTION

Hum is a low-pitched, repetitive sound that resembles buzz. Its fundamental frequency is 60 or 120 cps. The source of hum is the 60 cps 117-volt power line. Some hum is audible in all receivers operated from such a source. When certain defects in a receiver develop, the hum becomes objectionably noticeable.

Objectionable hum is a very common fault in radio receivers. It may be heard as an accompaniment to the desired sound signal. It may mix with the signal and cause distortion. A serviceman may not be able to tell that hum is the cause of distortion unless he listens carefully to the symptoms in a quiet room with the volume control setting low.

In this lesson we will discuss what causes an excessive level of hum to develop in a-c and a-c/d-c receivers; how to localize the trouble to its source; and how to correct it.

We can divide hum into two basic categories: 1. Hum that can be heard even when the volume control is set all the way to minimum. 2. Hum that is *not* heard when the volume control is set at minimum. The troubleshooting procedure for one kind of hum is different from the troubleshooting procedure for the other kind. Therefore, correctly identifying the kind of hum present is the first step in efficient troubleshooting.

35-1. HUM HEARD EVEN WITH VOLUME CONTROL AT MINIMUM SETTING

Let's suppose we are going to find the cause of hum in a line-operated radio receiver. We plug the set in and hear hum at normal volume control settings, so we turn the volume control all the way down. We still hear hum. Therefore, we know that we must apply the troubleshooting procedures for hum heard even with the volume control at minimum setting.

Caution: Servicing a radio receiver for hum in many cases requires a quiet repair shop, because a level of hum that can prove annoying in the customer's home may easily be masked by noises present in the shop.

When making a listening test for hum, let the speaker remain in its cabinet. A speaker deprived of a baffle will not reproduce low frequencies (such as 60 cps and 120 cps hum) as loudly as when the speaker is properly mounted on its cabinet. The serviceman who overlooks this fact may incorrectly consider the hum level in a particular set negligible, whereas it is negligible only with the cabinet off. Remember, the customer plays the receiver in a quiet room in his home, with the speaker in its cabinet; he probably plays it sometimes at relatively low volume control settings. Try to duplicate such conditions when you are making listening tests for hum in your shop.

The most likely cause of hum that is audible with the volume control set at minimum is a defect in the power supply or audio section of the receiver. Since it is simplest to check the tubes in these stages, we do this first.

Checking Rectifier and Audio Tubes. Begin your check by inspecting the rectifier tube for sparking, which is commonly produced by arcing between cathode and plate of the tube; also look for a bluish glow between cathode and plate. Either condition

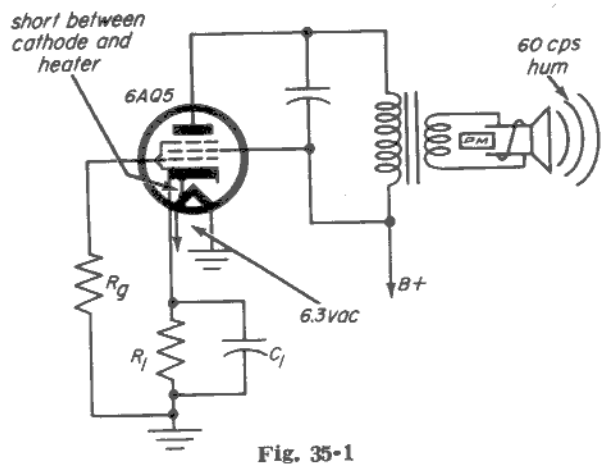


Fig. 35-1

indicates that the rectifier tube is not functioning properly.

However, the fault may not be due to a defect in the tube itself. A leaky or shorted filter capacitor may be the trouble. If you replace the rectifier tube without checking the filter capacitor first, you may damage the new tube.

Even if you do not see sparking or a bluish glow, the rectifier tube may be shorted. Test it in a tube checker or, if you don't have a tube checker handy, by substitution.

Since you can check the power tube easily at this point, you should check it for cathode-to-heater leakage, a common cause of the type of hum we are discussing.

Cathode to Heater Leakage. The best way to understand cathode-to-heater leakage is to compare it with an actual cathode-to-heater short. Let's consider the circuit of a typical audio power-output stage shown in Fig. 35-1. A short is shown between cathode and heater of the 6AQ5.

The short causes the a-c 60-cps heater voltage to be impressed across the cathode resistor. Normally, only a d-c bias voltage appears across the resistor. The a-c voltage across the cathode resistor causes the bias of the tube to vary 60 times per second, causing an amplified hum signal to appear at the output of the stage.

Heater-to-cathode leakage, which produces hum much in the same manner as does a short, occurs when there is a breakdown of the insulation between the cathode and the heater. As a result, the cathode emits electrons in the direction of the heater. This emission increases or decreases in step with the a-c voltage variations of the filament. Therefore, a varying current flows from the cathode to the heater to ground, and from ground through the cathode resistor, back to cathode. Just as in the case of the direct short, the condition causes the bias of the tube to vary 60 times per second and results in the appearance of an amplified hum signal at the output of the stage.

Heater-to-grid leakage in the power amplifier can also be a source of hum.

If the power amplifier tube checks all right, test the detector–1st audio amplifier for a cathode-heater or heater-grid short in a tube checker, or substitute another tube. In the case of a receiver using push-pull output stages, the phase inverter as well as the power amplifier tubes should be checked for the same defects.

If no defect is revealed by the tests previously described, the power-supply circuit requires checking. Turn off the set, and remove it from the cabinet, to permit the needed tests to be made.

Causes of Hum in Rectifier Circuit. In a typical a-c receiver, the power-supply circuit will be similar to the one illustrated in Fig. 35-2. The circuit uses a power

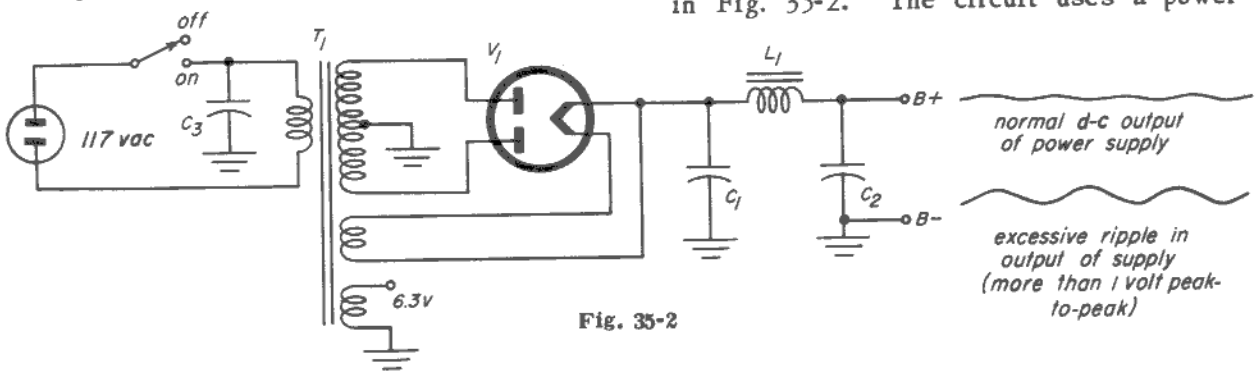


Fig. 35-2

transformer with a center-tapped secondary (T_1); full-wave rectifier tube (V_1); filter choke (L_1); and two filter capacitors (C_1 and C_2). C_3 is a line bypass capacitor used to eliminate noise.

The commonest source of hum in this circuit is a considerable decrease in the capacitance of one of the electrolytic filter capacitors (C_1 or C_2). When such a decrease occurs (due to the drying out of the electrolyte or because of some other defect), a substantial a-c ripple develops in the output of the power supply (Fig. 35-2). Normally, the output of the power supply is a relatively smooth d-c voltage. The ripple appears because the filter capacitance present is not large enough to eliminate it. The fundamental frequency of the ripple is 120 cps, since the rectifier is a full-wave type, and conducts during both halves of the cycle. Harmonics of the 120 cps ripple voltage are also present, but you need not concern yourself with them. The 120 cps a-c ripple is fed to the plates and screen grids of the various tubes in the receiver; it is amplified and applied to the speaker, which reproduces it as hum.

A partial or complete short in choke coil L_1 may also result in 120-cps hum, due to the inability of C_1 and C_2 to bypass the excessive hum current that is produced under such conditions.

In an a-c/d-c receiver, the rectifier power-supply circuit will generally resemble the one illustrated in Fig. 35-3. The circuit in this case consists of a half wave rectifier tube (V_1); a filter resistor (R_1); and input and output filter capacitors (C_1 and C_2). Hum will be heard if C_1 or C_2 lose capacitance, or if the resistance of R_1 decreases substantially. The frequency of the hum produced by filter-component defects in the a-c/d-c receiver will be 60 cps, as compared to the higher-pitched 120 cps hum audible when comparable defects occur in an a-c set using a full-wave power supply.

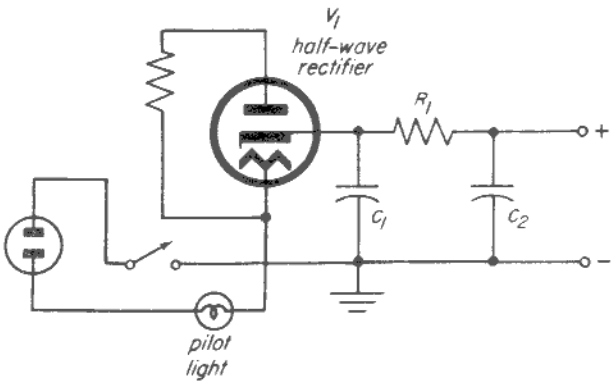


Fig. 35-3

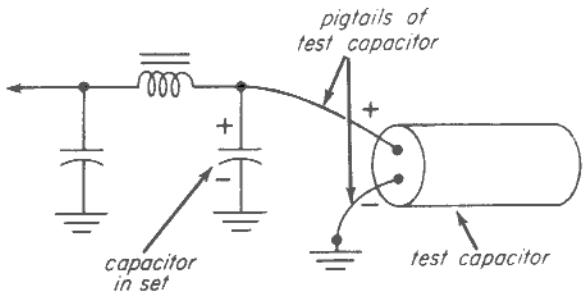


Fig. 35-4

Testing Rectifier Filter Components. To check the rectifier filter capacitors for a loss of capacitance, bridge them with capacitors that you know to be good, of the same capacitance and voltage rating. When we say, *bridge them*, we mean connect an identtical capacitor between the points to which the original capacitor connects (Fig. 35-4). Make sure you observe correct polarity—that is, connect the positive lead of the test capacitor to the point where the positive lead of the original capacitor connects; connect the negative lead of the test capacitor to the point where the negative pigtail of the original capacitor goes. If the hum symptoms disappear, the filter capacitor that is being bridged should be replaced. When one section of a dual filter capacitor is bad, replace the entire capacitor; the other section will probably not remain normal much longer anyway.

In the infrequent cases where hum is due to leakage in a filter capacitor (Fig. 35-5*a*) or an open in the common negative of a dual-section filter (see Fig. 35-5*b*), bridging the defective filter section will not eliminate the hum. In the first case, the leakage is not removed when the filter capacitor is bridged; the symptoms persist. The leak prevents an adequately large charge from being built up across the capacitor – that is, the leakage resistance (R_1 in Fig. 35-5*a*) discharges the capa-

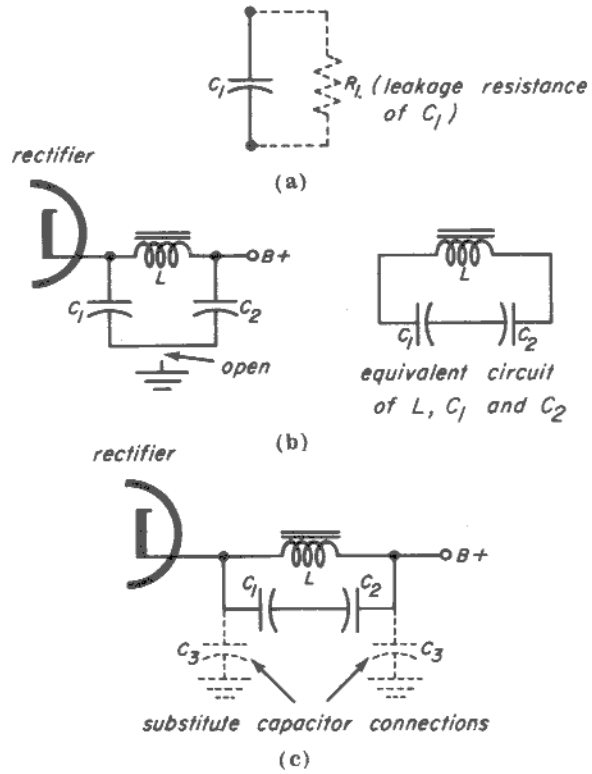


Fig. 35-5

citor before it can charge fully, impairing the capacitor's filtering action.

In the case of an open in the common negative lead of a dual-section filter capacitor (Fig. 35-5*b*), the two filter capacitors are in series with each other across the choke, and effectively short-circuit it. The short is present even when a substitute capacitor is connected between the input or output of the choke and ground (Fig. 35-5*c*). Bridging tests are therefore ineffective in localizing this kind of trouble. In order to test for the defect, the original dual- or triple-section capacitor must be disconnected and new capacitors substituted. Such a substitution is recommended if a bridging test does not eliminate hum, and the symptoms indicate that the power-supply may be a source of the trouble – i.e., if substantial hum is heard when the volume-control setting is minimum.

In some a-c receivers, speaker field coils are used as filter chokes. In such sets, excessive hum can (in rare instances) be due to a reduced value of choke inductance (the result of shorted turns in the field-coil winding). To test for such trouble, measure the d-c resistance of the field-coil winding, with an ohmmeter, making sure that the resistance does not differ appreciably from the value given in the set manufacturer's service notes. If the resistance is too low, several turns are probably shorted. A replacement of the speaker is called for in such a case. In some instances, it is practical to replace the field coil only; most of the time though, it is more economical to substitute an entire new speaker.

Hum Due to Power Transformer Defects. A very loud and annoying hum is likely to develop in an a-c receiver when one half of a power transformer center-tapped secondary winding open-circuits, as shown in Fig. 35-6. A 60-cps instead of 120-cps hum is produced in this case, because the normally full-wave rectifier now operates as a half-wave rectifying device. Hum is heard because the power supply filter components were intended to eliminate 120 cps, and do not have the values necessary to remove 60-cps hum.

A disconnected transformer wire at the rectifier-tube socket, as well as an open (burned-out) transformer-secondary winding, may be the source of the trouble just mentioned.

Similar symptoms will be produced if the secondary winding shorts internally (a rare occurrence).

Visual inspection will quickly reveal whether the transformer lead is disconnected at the tube socket. An a-c voltage check across each secondary winding will indicate whether an open exists here. If no a-c voltage is measured across one of the

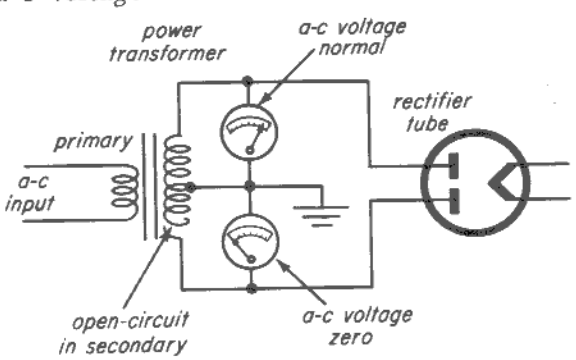


Fig. 35-6

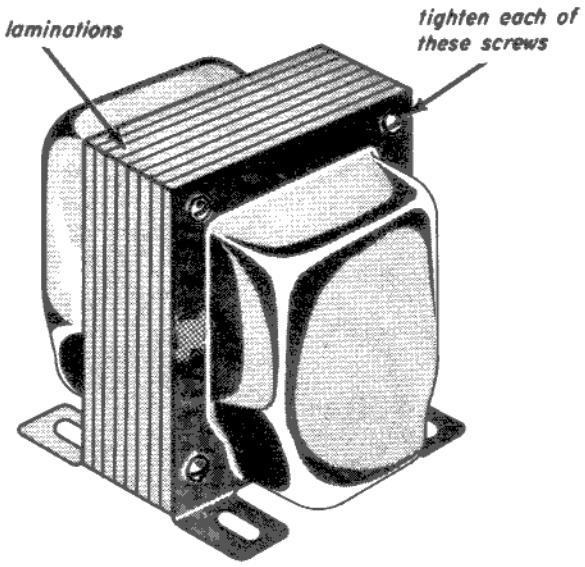


Fig. 35-7

windings, an open-circuit is probably present; resistance-check the winding to verify this. A shorted winding will cause the transformer to smoke.

Clues pointing to the presence of one of the defects just described are:

1. Greatly reduced d-c voltage at the output of the power supply.

2. The presence of 60-cps hum. The serviceman can learn to distinguish between 60 and 120 cps hum by disconnecting the input filter capacitor of an a-c set, then doing the same in an a-c/d-c set, and comparing the pitch of the two sounds.

Sometimes, a buzzing sound that resembles hum emanates from an a-c receiver. Loose laminations in the core of the power transformer are a frequent source of trouble. The transformer vibrates when this condition is present, causing an audible buzz. Tightening the four screws (three are shown in Fig. 35-7) will usually correct such trouble.

Checking the Power Amplifier Stage. After you have checked the power-supply section of an a-c or a-c/d-c set for defects that might cause hum, and have also tested the power amplifier tube as described earlier in this booklet, the next step is to check the power amplifier stage.

A short between the heater and control grid of the power amplifier tube sometimes occurs at the *tube socket*. The condition may be due to an exposed heater wire touching either the control grid socket pin, or a component pigtail leading to this socket pin, thus causing a 60-cps signal to be injected into the power amplifier (see Fig. 35-8*a*). The setting of the volume control will have no effect on the resultant loud hum. Station signals will not be audible, because the impedance between power amplifier grid and ground is very low (Fig. 35-8*b*) and the input signal applied between grid and ground will therefore be eliminated.

A visual check will quickly reveal the trouble. It is easily remedied by removing the heater wire away from the control-grid socket contact.

Some higher-priced console radio receivers (either a-c or a-c/d-c in type) use push-pull audio power amplifier circuits, instead of a single-tube type of circuit. Push-pull audio amplifiers permit the de-

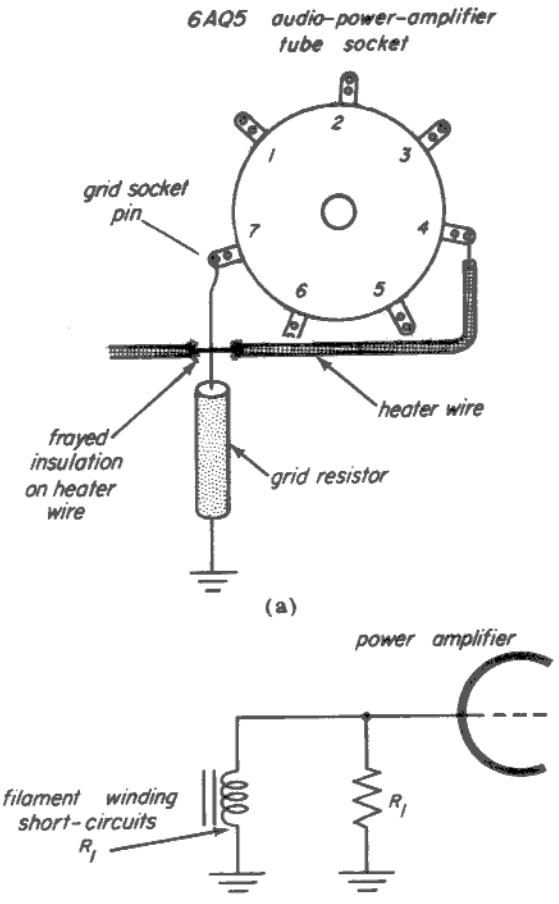


Fig. 35-8

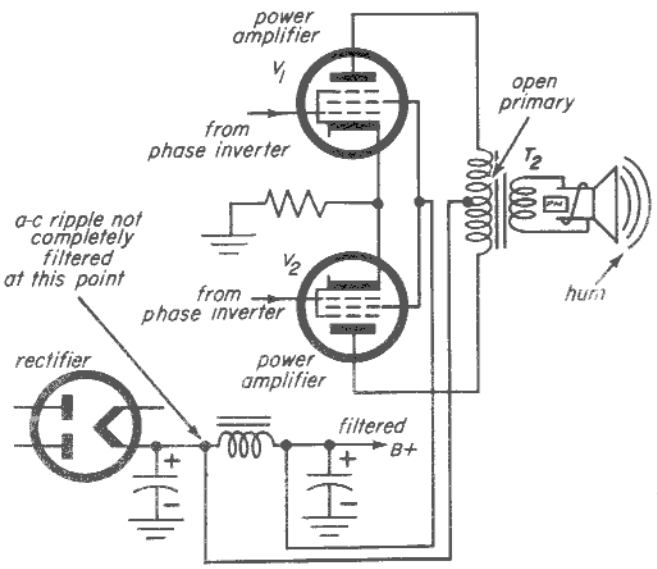


Fig. 35-9

livery of large amounts of audio power to the speaker, with less distortion.

Push-pull tubes must be electrically balanced; that is, the input and output signals of one tube must be the same as the corresponding signals of the other one. If this condition is not satisfied, hum as well as distortion may be heard. Electrical balance requires that the following conditions be met:

1. Both tubes must have practically identical characteristics. The cathode emission of both tubes must be the same.

2. The plate, screen grid, and bias voltages must be the same for both tubes.

3. The primary winding of the output transformer must be center-tapped to provide a balanced plate circuit.

Let's assume that too much hum is heard in a receiver using push-pull output stages, with the volume control setting minimum. To determine whether unbalanced power amplifier tubes are responsible for the hum, test both tubes in a tube checker, noting particularly whether the emission reading is the same for both. If it isn't, replace the weaker tube or (preferably) both tubes. A number of test substitutions will generally have to be made to locate a pair of well-matched tubes. If the tubes aren't to blame, check the plate-to-ground voltages of both tubes; these voltages should be equal. If zero volts is measured at the plate of one tube (V_1) Fig. 35-9, whereas the plate-to-ground voltage of the other tube is normal, one-half of the output transformer primary is probably open. Such a defect is likely to produce distortion and reduced volume as well as hum. If a resistance check reveals that the transformer (T_2) has an open winding, replace the unit, making sure that the replacement has the same characteristics as the original transformer—i.e., that it matches the tubes, and the speaker voice-coil impedance.

In order to understand why an imbalance in push-pull power amplifier stages often results in hum, let's refer to Fig. 35-9. Note that the plate voltages for the push-pull tubes do *not* come from a well-filtered point of the power supply. But, the needed d-c voltage is taken off at the 5Y3 filament, at which point a large a-c ripple exists. The a-c ripple present at this point does not cause hum to be heard in a normally operating receiver using balanced push-pull amplifier tubes. The reason is that the ripple (hum) voltages cancel or buck out in the balanced center-tapped primary circuit of the output transformer. If imbalance develops in a push-pull amplifier, however, the ripple voltages will not entirely cancel, and audible hum may result.

If the plate voltages were taken off at the output side of the choke, instead of at the 5Y3 filament point as shown, hum would not be produced even if an imbalance occurred in the push-pull circuit. Many set manufacturers, however, prefer to feed the plates of push-pull tubes from the choke input because this method permits manufacturing economies. A larger filter choke would be needed if the push-pull tubes were fed from the output side of the choke, since the choke would, in the latter case, have to pass the heavy plate currents of the power amplifier tubes (amounting to approximately 70 ma), in addition to the plate currents of the other tubes.

Hum may be injected into the control grid of a push-pull amplifier because of an internal cathode-heater short, or a grid-to-heater short. A similar defect may occur at the phase inverter (Fig. 35-10).

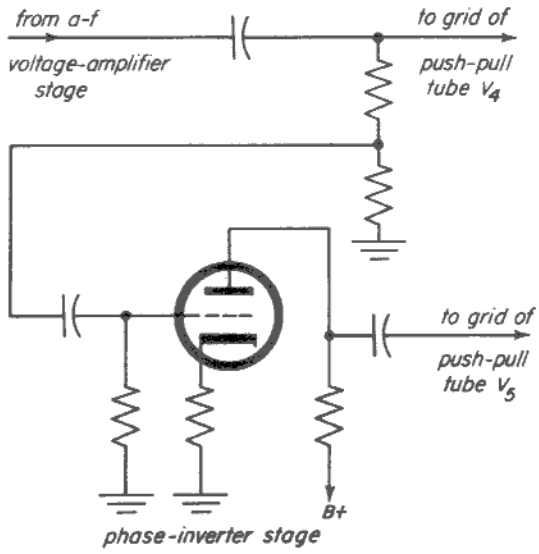


Fig. 35-10

Hum Sources in Audio Voltage Amplifiers. If no fault can be found with the power supply, audio tubes, and the circuit components of stages as far back (but not including) the audio-voltage amplifiers, the audio-voltage amplifier should be checked. Figure 35-11 shows the circuit of a typical detector-audio-voltage amplifier stage commonly used in both a-c and a-c/d-c sets. This stage is more sensitive to hum than the power amplifier because a hum signal at its input will be amplified by both the audio voltage amplifier and the power amplifier, instead of the power amplifier alone.

Possible sources of hum in this stage include a short between heater and grid (at the tube socket); an open in the grid resistor (R_1); or a missing tube shield (in cases where a shield is normally employed over the tube). Use of a glass tube, which has no shielding, in place of a metal one, may be the cause of hum.

An open grid resistor causes the grid in the tube to act as an antenna for the 60-cycle hum fields radiated from line and filament wiring, insufficiently-shielded power transformers, etc. A missing tube shield permits nearby hum fields to be coupled to the grid as well as the diode section of the detector–first audio amplifier.

To determine whether a missing tube shield is the source of hum, add a shield around the detector-first audio amplifier

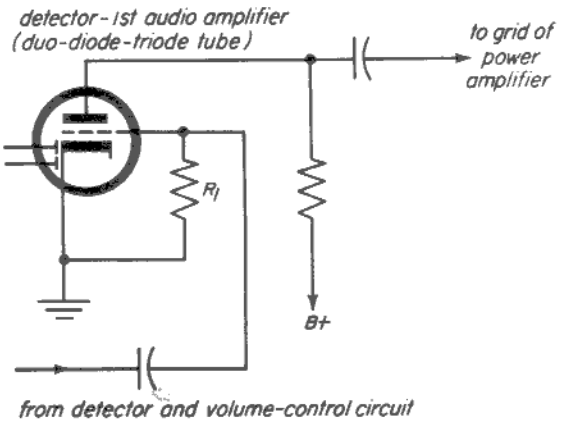


Fig. 35-11

tube and note whether hum is eliminated. If you see shield-mounting contacts around a tube, you can feel certain that a shield belongs there. In some cases, however, the only way to tell if a shield was originally present is to put one over the tube and note the results.

35-2. HUM AUDIBLE AT NORMAL BUT NOT AT MINIMUM VOLUME CONTROL SETTING, WITH STATION TUNED IN OR OUT

At this point in the lesson, we know the most common causes of hum that is excessive even with the volume control turned down to minimum. Assume, however, that in checking the receiver, we find that hum is not unduly noticeable until the volume control is advanced to its normal position.

If hum is present even when the tuning dial is in an off-station position, the trouble will most likely be found in the circuit that feeds the detected signal into the audio voltage-amplifier stage – the detector and volume-control circuit. A typical detector and volume control circuit found in many types of a-c or a-c/d-c receivers is shown in Fig. 35-12.

An exposed heater wire touching at points A, B, C or D in Fig. 35-12 will result in hum. Trouble of this kind will be readily revealed by a visual inspection.

An improperly-grounded i-f shield can (T_2, Fig. 35-12) may be the source of hum. Hum is likely to be induced into the i-f transformer from adjacent stray magnetic

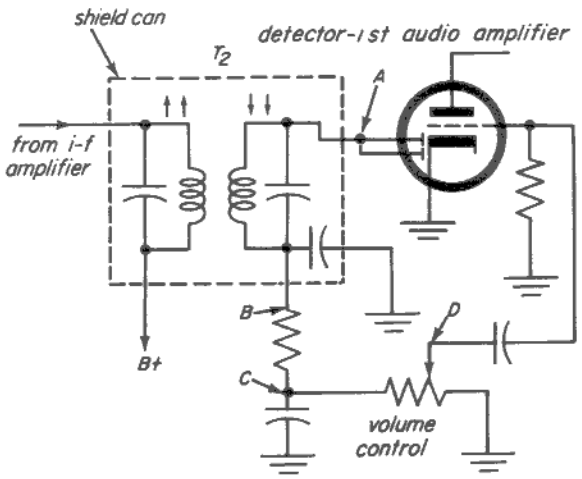


Fig. 35-12

fields under such conditions. Make sure that the can makes good contact with the chassis to rule out this possible source of trouble. If pressing the can against chassis causes hum to be eliminated, the contact of can and chassis is imperfect.

Poor electrical contact between the moving arm and the resistance element of the volume control may be the source of hum. If the volume control seems touchy —i.e., the hum starts or stops when the control is slightly adjusted or tapped— the unit is faulty. Screeching sounds may be heard as well as hum when there is an open-circuit in a volume control. The symptoms will disappear when a 1-megohm resistor is connected between the end terminal lugs of the control. Connection of a voltmeter (which has been set to a high voltage range) across the end terminal lugs of the control will have the same effect, providing a clue to the trouble. To confirm that the volume control is defective, make a resistance check between the movable arm (usually connected to the center lug) and each end of the potentiometer (first one end, then the other, as illustrated in Fig. 35-13).

The resistance measured should increase or decrease gradually and smoothly

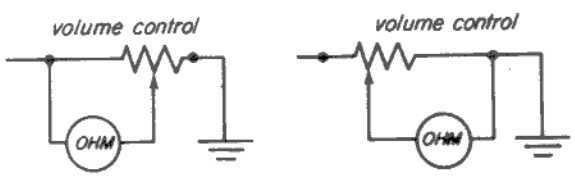


Fig. 35-13

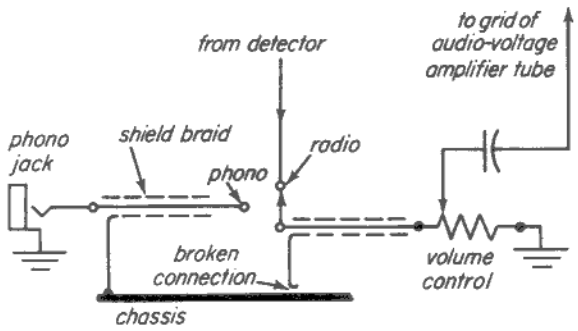


Fig. 35-14

as the shaft of the control is rotated from one extreme to the other. If the change in resistance is erratic, or if infinite resistance is read at any time during the rotation of the shaft, the control is defective, and should be cleaned or replaced.

Another cause of hum that is audible only when the volume control setting is advanced, with the set either tuned to or off a a station, is hum pickup by unshielded wires. Such trouble is particularly likely to be found in a radio that is part of a phono-radio combination, or has a phono jack that permits a separate record-player to be connected to it (see Fig. 35-14). The lead running from the phono jack to the phono-radio selector switch, and from the switch to the volume control, is long enough to pick up hum from the phonograph motor, line or filament wiring, or stray magnetic fields.

In many receivers, the lead from phono jack to switch to volume control is shielded; the shield braid is connected to chassis, as shown in Fig. 35-14. In such sets, if hum is heard with the volume control in its normally advanced position, check the shielded lead, noting whether the shield is properly connected to chassis. In some receivers, instead of a shielded lead, two leads that have been twisted together run from the phono jack to the phono-radio selector switch. Little or no hum will be induced in this twisted pair as long as the wires hug the chassis. If the dress of the wires is changed, however, and they are positioned away from the chassis wall and close to a strong magnetic-hum field, excessive hum is likely to be audible.

Faulty tube shielding is another possible cause of hum that is audible only when the

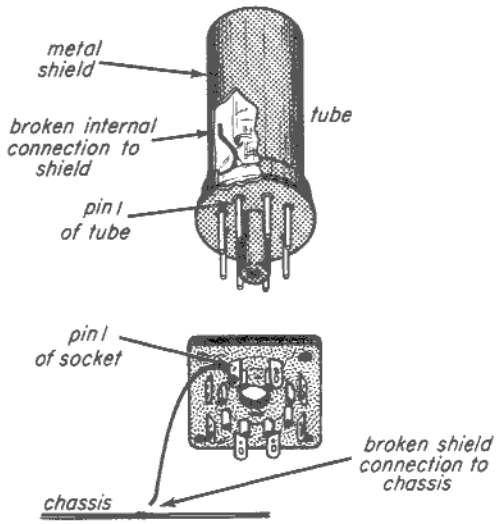


Fig. 35-15

volume control setting is advanced, with the set tuned to or off a station. The detector diode is part of the duo-diode-triode tube that also services as the audio voltage amplifier. Some receivers use glass-type detector-audio tubes and others (older sets) use metal tubes. In the metal type, the metal tube envelope serves as a shield. The envelope usually connects to pin 1 of the tube socket. Pin 1, in turn, connects to chassis, returning the shield to ground and thus making it effective.

Hum is sometimes caused by a disconnected lead at pin 1, or a disconnected lead to the envelope or shell within the tube itself (see Fig. 35-15). Inspection will reveal the first trouble; a continuity check between the metal shell and socket pin 1 will uncover the second. Make sure that the ohmmeter test prod makes good contact with the tube envelope by scraping the paint away from the envelope at the point to which the test prod is held. Use the test prod for this scraping job.

35-3. MODULATION HUM

Up to this point in the lesson, we have considered hum troubles with the following characteristics:

1. Excessive hum that is noticeable even when the volume control is at minimum setting.

2. Hum that is noticeable only when the volume control is at a normal or above-normal setting, and can be heard even when a station is not being received.

We now come to a type of hum that is commonly audible *only* when a station is being received. This kind of hum is called *modulation hum*, because it gets through the radio by modulating or riding in on the received signal. Modulation hum can develop because of defects in r-f, i-f, or power-supply stages of the receiver.

Cathode-to-heater leakage in an i-f, oscillator, or r-f amplifier tube is a common cause of hum.

Let's consider the effects of such cathode-to-heater leakage in a typical i-f amplifier stage (see Fig. 35-16). The purpose of this stage, as we learned in an earlier lesson, is to amplify the i-f signal that is fed to its grid from the output of the converter. Assume that the radio receiver is tuned to a station that is transmitting an r-f carrier signal only (no speech or music). The signal that reaches the i-f grid is amplified by the i-f amplifier; the shape of the signal at the plate of the i-f tube resembles the waveform at this point shown in Fig. 35-17*a*. Note that the plate signal does not vary in amplitude, indicating that no modulation has been applied to it.

Let's consider the effects of hum on such an i-f signal. Cathode-to-heater leakage in the i-f tube will cause the cathode-to-ground voltage to vary at a 60-cps rate. This means that the bias will fluctuate at the same rate, causing a corresponding variation in the plate current of the tube.

When no station is being received, the hum voltages built up across the tuned plate circuit will generally be negligible. The impedance of the plate coil is very low at 60 cps, and the coil will act as a short-circuit for the hum signal.

If a station signal is coming in, however, the tube will operate along a nonlinear portion of its e_g-i_p characteristic, due to improper bias. Cathode-heater leakage

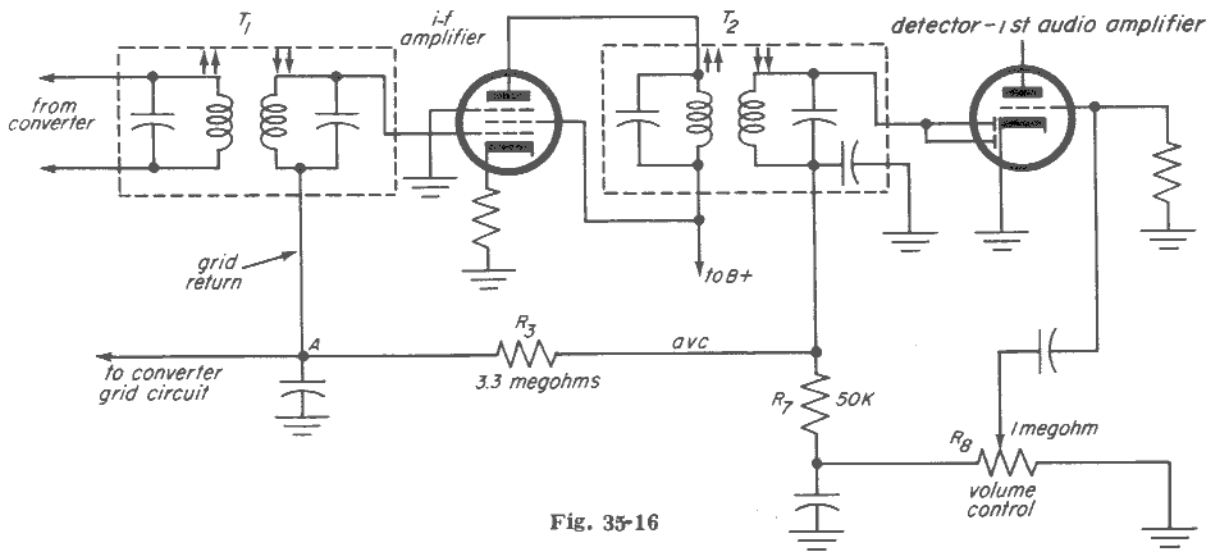


Fig. 35-16

effectively shunts the low impedance of the heater circuit across the cathode resistor (see Fig. 35-17*b*); the bias of the tube is changed in consequence, tending to cause nonlinear tube operation. Grid current flow during the positive alterations of the large hum signal also promotes nonlinear operation of the tube. The current causes a negative grid-to-ground voltage to develop which contributes to the improper biasing of the tube.

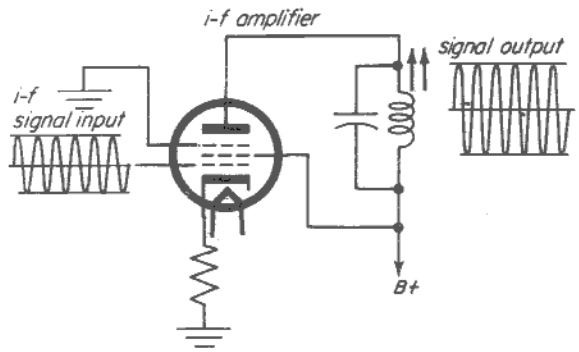
The i-f and hum signals beat together, forming sum and difference frequencies that represent hum modulation. When these undesired i-f signals are detected (along with the desired i-f signals), the original hum signal is reproduced.

The envelope of the waveform at the plate of the i-f amplifier tube is hum-modulated when cathode-heater leakage exists in this tube (see Fig. 35-17*b*).

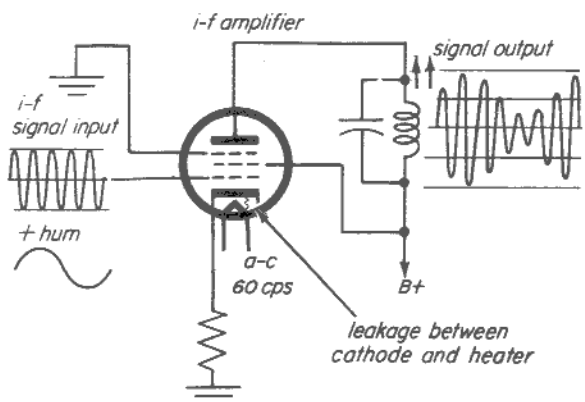
Tube Tests for Modulation Hum. In addition to cathode-to-heater leakage in the r-f tube, cathode-to-heater leakage in the converter and r-f amplifier tubes are common sources of modulation hum and should be checked for with a tube tester or by substitution.

Power Supply Sources of Modulation Hum. A common source of modulation hum in a-c/d-c receivers is an open rectifier plate-bypass capacitor, C_1, Fig. 35-18*a*. When such a capacitor opens, r-f signals may not be completely filtered out of the power supply. Therefore these signals (which flow through r-f and i-f tubes) are likely to be modulated by the hum voltages present in the supply, and modulation hum will result.

You may wonder what r-f signals are doing in the power supply. These signals



(a)



(b)

Fig. 35-17

are supposed to be filtered out of the plate and screen circuits of the r-f and i-f tubes by the power-supply electrolytic filter capacitors and smaller screen-bypass capacitors. The inductance present in electrolytic filter capacitors, however, offers a substantial impedance to high-frequency (r-f) signals, and may prevent such signals from being adequately filtered out. If r-f signal currents get into the rectifier tube, they will be modulated by the hum present in this stage. Modulation hum results. Radiation of the hum-modulated r-f signals from the line cord of the set to the loop or ferrite-rod antenna used in many receivers also contributes to the introduction of modulation hum. The addition of an r-f bypass capacitor between rectifier plate and cathode, or plate and ground, filters r-f signals out of the power supply and helps minimize the possibility of modulation hum being introduced via this source.

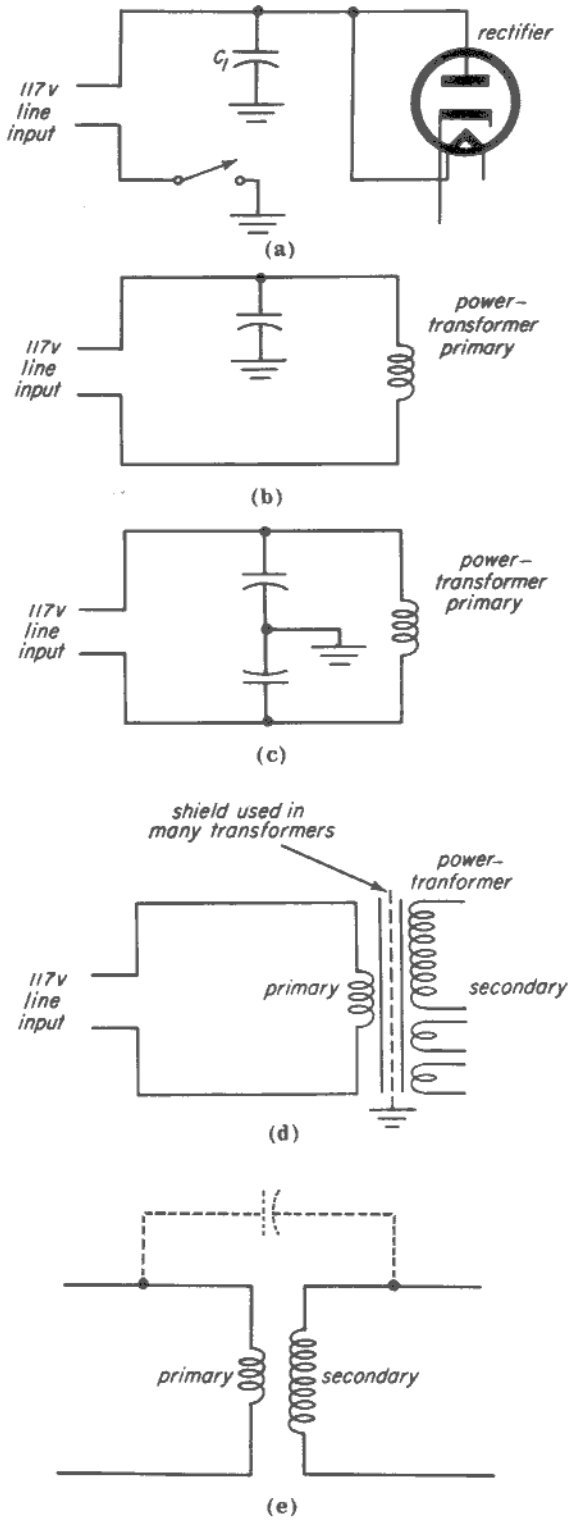


Fig. 35-18

To check whether an open rectifier-plate bypass capacitor is the source of modulation hum, place a capacitor of the same capacitance and voltage rating parallel with it. If the hum symptoms are eliminated, the original capacitor is defective and should be replaced.

In an a-c receiver, one or two bypass capacitors (Fig. 35-18*b*, *c*) are commonly connected in parallel with the transformer primary circuit. The capacitors are intended to keep r-f signals out of the line. Power lines tend to pick up such signals. If the line isn't properly bypassed and there is no shielding between primary and secondary windings of the power transformer (Fig. 35-18*d*, indicates location of such shielding) r-f signals may get from primary to secondary of the power transformer by way of the capacitive coupling present between the two windings (Fig. 35-18*e*). From the secondary, r-f signals tend to get into the output of the power supply. Since the r-f signals pass through a nonlinear device (the rectifier tube), they are modulated by the hum voltages present in this stage. The inefficiency of the filter capacitors at radio frequencies is likely to permit the hum-modulated r-f signals to be fed to the plates and screen grids of the r-f/i-f tubes; modulation hum will result.

To check a bypass capacitor in the power transformer primary circuit of an a-c set, simply connect an identical capacitor across the pigtails of the suspect unit and note whether modulation hum disappears.

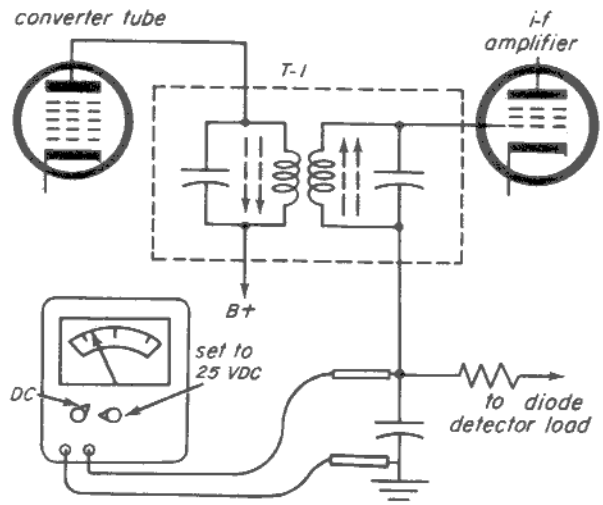


Fig. 35-19

If the tube and component tests just described do not reveal the source of modulation hum, the stage tests discussed in the next section of the lesson will have to be made.

Sources of Modulation Hum in I-F Stage. If the i-f tube has been checked for cathode-heater leakage and found normal, the next step is to inspect components for short-circuits. A short between a bare heater wire and cathode may be the cause of modulation hum. Another possible (but unlikely) source of trouble is a short between a heater wire and the avc line. Symptoms likely to be present under such conditions may be summarized as follows:

1. The hum present will be tunable, i.e., it will come in at loudest volume when a station is tuned to. In this respect, the hum is .similar to conventional modulation hum.

2. No station will be audible; the hum will drown out recognizable reception.

3. Some hum will be noted, chiefly at maximum volume setting, even when the set is tuned off a station. This is so because some hum voltage is developed across the volume control, and transferred to the audio stages.

Another possible source of modulation hum is a loose connection of an i-f shield case to chassis. The shielding effect of the case may be lost under such conditions.

Visual inspection will generally reveal whether any of the troubles cited are present. If visual inspection reveals no trouble, and the technician is uncertain whether the i-f stage is the source of the symptoms, he can check this stage with a signal generator.

Checking I-F Stage for Modulation Hum with a Signal Generator. We are assuming that modulation hum is being heard along with the speech or music. First, tune in a station, adjusting the volume control to produce a normal volume of sound. Next, measure the avc voltage of the i-f amplifier stage, connecting the voltmeter as shown in Fig. 35-19. Leave the voltmeter connected in this way. Turn off the set and connect a 0.01-μf capacitor from the plate of the converter tube to chassis (as shown in Fig. 35-20), to prevent broadcast signals from reaching the grid of the i-f amplifier tube. Turn the set on again. Connect an r-f signal generator between grid and ground of the i-f amplifier tube. If the set is an a-c/d-c type and a floating ground connection is used, make sure that the generator ground lead goes to B– instead of to chassis. Turn the generator modulation on, and advance the modulation control, if there is one, to 30%. Adjust the generator frequency to the receiver intermediate frequency. When the generator settings are correct, the modulating signal will be heard in the receiver speaker.

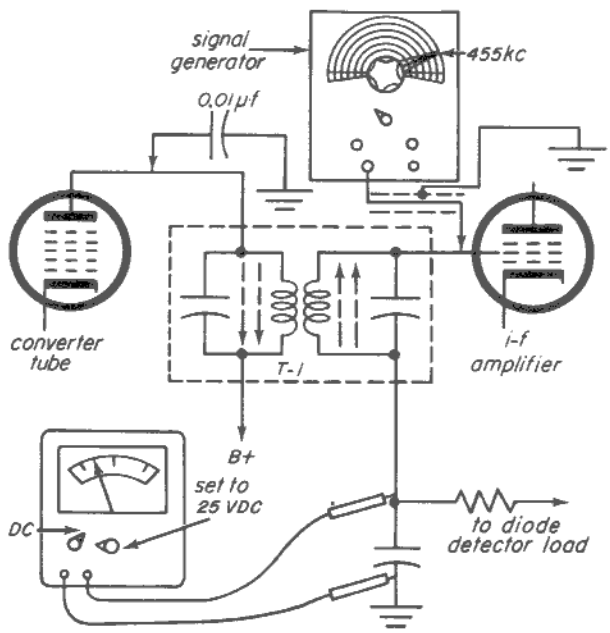


Fig. 35-20

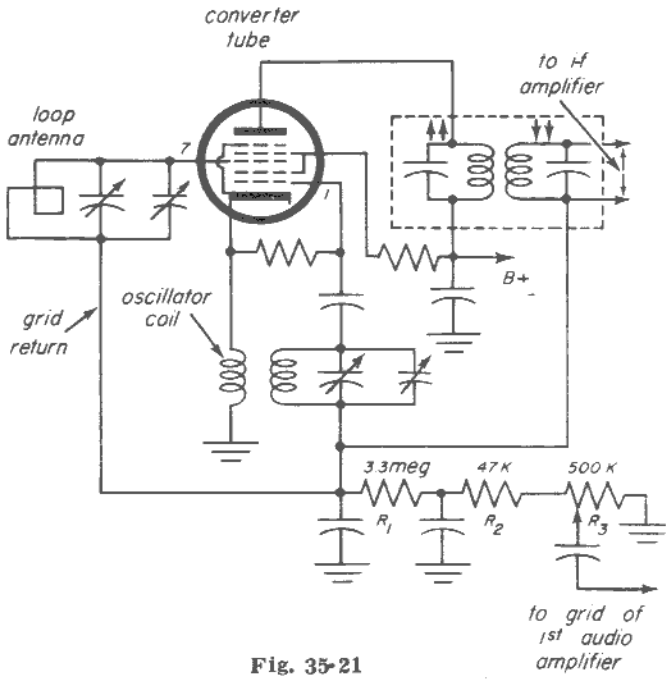


Fig. 35-21

Adjust the r-f gain control of the generator until the avc voltage is the same as the voltage measured when a station signal was being received. Now switch the generator modulation off, allowing the unmodulated output of the generator to feed into the i-f grid. Note if hum can be heard. If it can, the i-f amplifier stage *is* the source of the modulation hum. If hum is *not* audible, the converter should be checked.

Sources of Modulation Hum in Converter Stage. Figure 35-21 shows a typical converter stage found in many a-c and a-c/d-c receivers. The purpose of the converter, you will recall, is to heterodyne the oscillator and r-f signals applied to it in order to produce the i-f signals needed for the i-f amplifier section.

The following defects in the converter stage may be responsible for modulation hum (it is assumed that the converter has been previously checked for cathode-heater leakage):

1. Open in the signal grid circuit. The avc resistor may be open-circuited; or the loop or loopstick antenna or antenna coil winding that connects to the converter r-f grid may be open. The open-circuit causes the converter grid electrode to act as an antenna, and pick up hum signals radiated from wires carrying 60-cycle current. A resistance check between converter grid and ground will readily reveal whether such an open circuit exists. Normally, the reading should be (see Fig. 35-21) the sum of R_1, R_2 and R_3 (the resistance of the converter winding is small enough to be neglected), or approximately 4 megohms.

2. Heater wiring is too close to converter grid or avc line. Inspection will reveal this condition. If you are not sure whether improper lead dress is the source of trouble, the suspect wire may be repositioned, and results noted.

3. The screen bypass capacitor is open. The screen-grid signal current can now be bypassed only by the power-supply filter capacitors. Since these are inefficient at radio frequencies, the r-f screen current is likely to flow through the rectifier tube. Modulation of the r-f screen-grid current by hum will result. The hum-modulated r-f signal voltage developed between converter screen-grid and ground will also appear between B+ and ground, causing the i-f signal at the plate of the converter tube to be similarly hum-modulated; modulation hum will be heard as a result.

Checking the Converter for Modulation Hum with a Signal Generator. In some instances, where the source of modulation hum seems obscure, you may want to find out whether or not the trouble is in the converter stage. To do this, first tune in a station and set the volume control so that normal volume is obtained, along with the desired modulation hum. Next, measure the avc voltage as explained in a preceding paragraph, allowing the voltmeter to remain connected to the circuit (refer to Fig. 35-20). Detune the receiver away from the station frequency and connect an r-f signal generator to the signal grid of the converter tube. Turn the generator audio modulation on and advance the modulation control (if there is one) to 30%. Tune the generator near the same frequency as the receiver dial setting and readjust the generator frequency until the audio modulating tone is heard. Adjust the generator r-f gain control until the avc voltage reading is the same as when

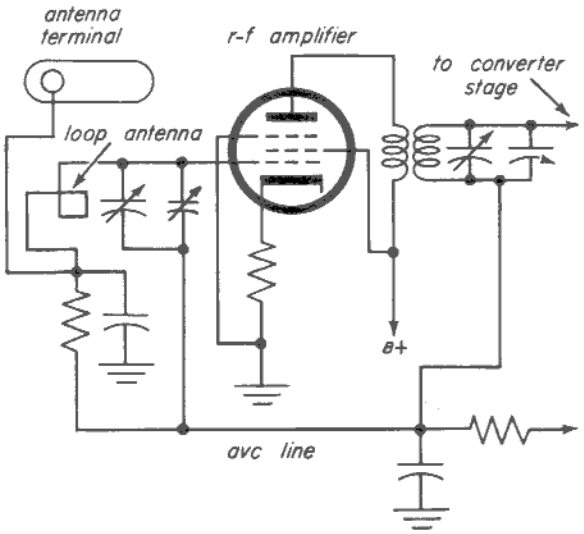


Fig. 35-22

a station signal was coming in. Turn off the generator modulation and listen for hum. If hum *is* audible, the converter stage is introducing it (assuming that the tests previously described show that the trouble is not in the i-f amplifier and power supply). If hum is *not* audible, the r-f amplifier should be checked next.

Checking the R-F Amplifier for Modulation Hum. A typical r-f amplifier stage found in a-c and a-c/d-c receivers is shown in Fig. 35-22. A loop antenna connects to the control grid of the tube. Provisions are also made for connecting an outside antenna, if desired.

If the r-f amplifier tube has been tested for cathode-heater leakage and found normal, check for the following possible sources of modulation hum:

1. Open in the grid circuit.

2. Open screen-bypass capacitor.

You can determine whether modulation hum is really originating in the r-f amplifier stage by following the procedure used for a comparable check of the converter.

Sources of Modulation Hum External to the Receiver. When the tests previously described reveal no fault in an r-f or i-f stage, the source of modulation hum may be external to the receiver.

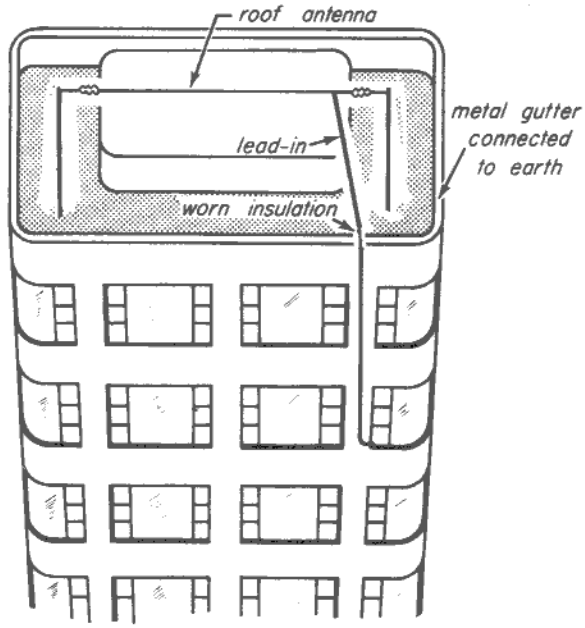


Fig. 35-23

The aerial of an a-c/d-c hot chassis set may be contacting some grounded point on the roof (see Fig. 35-23). The resistance between aerial and ground may be either very low or quite high. Short-circuits of this kind are particularly likely to occur when the roof is wet; surfaces on it that are normally well insulated from ground become more conductive in this case. If the plug is inserted into the outlet in such a way as to make the chassis hot (see Fig. 35-24), the effective ground at the aerial will cause an appreciable percentage of the line voltage to be impressed across L_1, the antenna primary winding.

Figure 35-24*a* shows the line cord of an a-c/d-c set before it is connected to the power outlet. In *b* of the figure, prong E of the plug has been connected to contact D of the outlet, and prong F of the plug has been connected to contact C of the outlet. As a result, the chassis of the receiver becomes hot. When the chassis is hot and there is leakage (a high-resistance short) from the antenna to earth ground, as shown in *c*, the effect is the same as if the output of the generator that supplies line power were applied to the antenna input circuit, as shown in the equivalent circuit of *d*. A substantial portion of the line voltage will be developed across L_1 in this case.

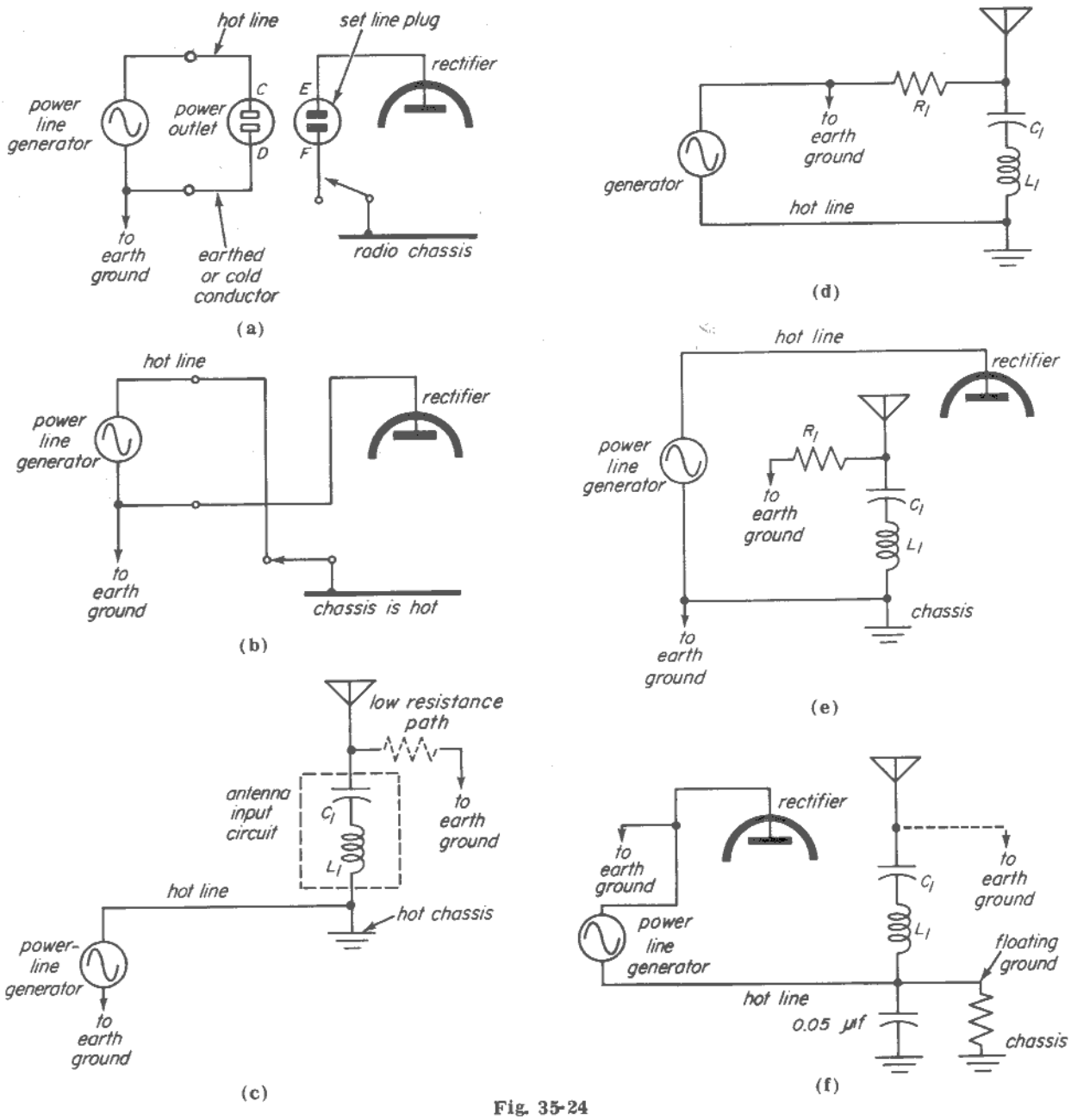


Fig. 35-24

If, on the other hand, the plug is connected so that prong F goes to contact D and prong E connects to contact C, the antenna and chassis will both be at ground potential and no line voltage will appear across C_1 and L_1, as shown in *e* of the figure.

A condition similar to the one illustrated in *c* and *d* is set up when the a-c/d-c radio has a floating ground, and the antenna is shorted to an earth point, as shown in *f*. Since the hot line of the 117-volt generator connects to the floating ground point, a-c line voltage is effectively applied across C_1 and L_1.

When line voltage appears across L_1, the large 60-cps line signal forces its way into the converter, and modulation hum results.

A quick check for such trouble is to reverse the line plug. If the modulation hum disappears, the condition just described is present. The reason the hum is eliminated when the line plug is reversed lies in the

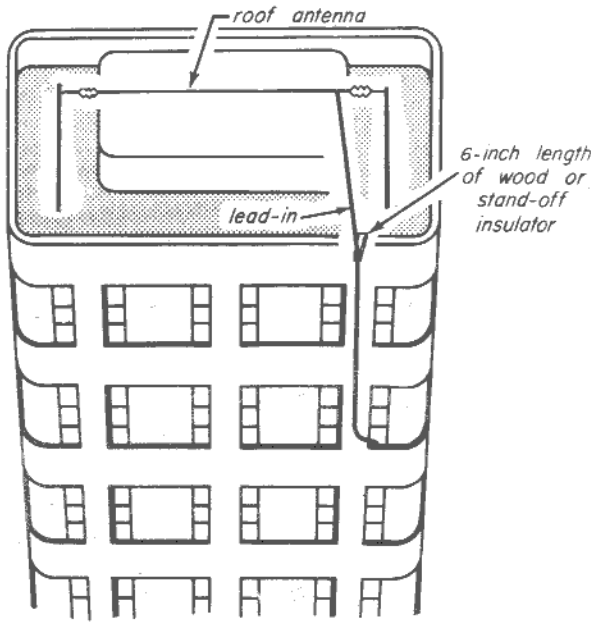


Fig. 35-25

fact that both ends of the antenna winding are now at the same potential.

If the condition is due to rain, the only remedy required is to reverse the line plug. In other cases, a roof check is called for, to locate and eliminate the antenna short to ground.

One example of such trouble is illustrated in Fig. 35-23. The lead-in wire in this case was installed in a manner permitting it to rest on the edge of a metal gutter. When the insulation of the lead-in subsequently became worn, the lead-in contacted the gutter. To avoid or remedy such trouble, the lead-in should be installed as indicated in Fig. 35-25, keeping it clear of the metal gutter. The height of the antenna wire should be at least 10 feet above the roof, especially if the roof is made of, or covered with, a metallic material. The antenna should be kept away from all power lines; if it has to run near one at some point, the antenna should be positioned at right angles to the line.

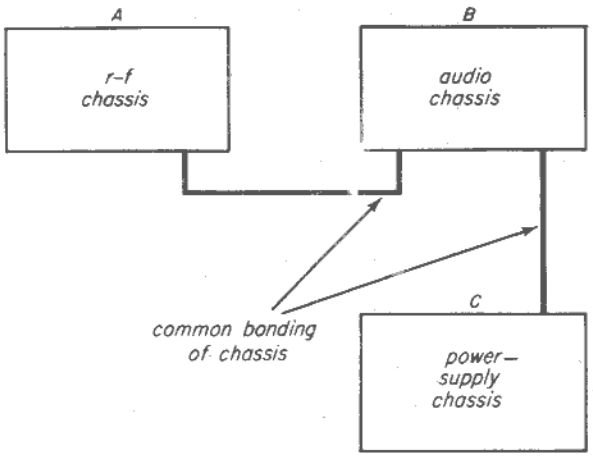


Fig. 35-26

Even when no roof antenna is used, hum that is minimized or eliminated by reversal of the line plug may be encountered. Pickup by the built-in loop or ferrite-rod antenna of hum signals radiating from power lines is responsible for the symptoms. When the plug is inserted into the outlet in such a way that the chassis is connected to the grounded side of the a-c power line, hum pickup is minimized.

Modulation Hum Due to Defective Connections Between Multiple Chassis. Some radio receivers—especially the larger and more expensive models—use several chassis. One chassis may contain the power supply, another the audio section, and the third the r-f section of the receiver. Modulation hum in such receivers is sometimes introduced by a poor connection between one or more chassis (Fig. 35-26). To test for the presence of such trouble, attach a lead from one chassis to the other (i.e., from Chassis A to B, then from B to C); if the hum disappears, the original connection between the chassis is poor. To remedy such trouble, improve the electrical contact between chassis by repairing the plug, socket, wire, or ground connection that is found defective.